Original Article

The Influence of Temporomandibular Joint Disorders and Mandibular Position on Visual Capacities: A Case-Control Study

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Abstract

Aims: To verify the possible association between the stomatognathic and the visual system by analyzing the effects that different mandibular postures may have on the accommodative capacity and ocular convergence and by assessing whether temporomandibular disorders (TMD) can influence visual abilities. **Materials and Methods:** A case-control study was performed during a 1-year period on a sample of 100 subjects (50 cases and 50 controls). The subjects underwent a gnathological examination, and two visual tests were performed in three different jaw positions: maximum intercuspation, resting position, and open mouth. The statistical analyses were performed using the software SPSS program based on *t*-test to compare the different jaw positions and the odds ratio to understand the prevalence of visual defects in TMD patients. **Results:** A statistically significant worsening was observed comparing the visual capacities measurements from the maximum intercuspation to the open mouth position; "case group" measurements showed a worsening trend compared to the "control group" (P value < 0.05 in all comparisons). Furthermore, the examinations showed statistically significant results with reference to the relationship between TMD and their negative influence on visual abilities (P value = 0.007 for convergence and P value = 0.012 for accommodation). **Conclusions:** Based on our data, TMD individuals performed worse in vision tests compared to healthy subjects and the presence of occlusal contacts appears to improve convergence and accommodation. The reduced reproducibility and accuracy of the orthoptic tests and the small sample number were the principal limitations of our study. The future perspective could be to investigate whether the visual apparatus could benefit from the treatment of stomatognathic disorders.

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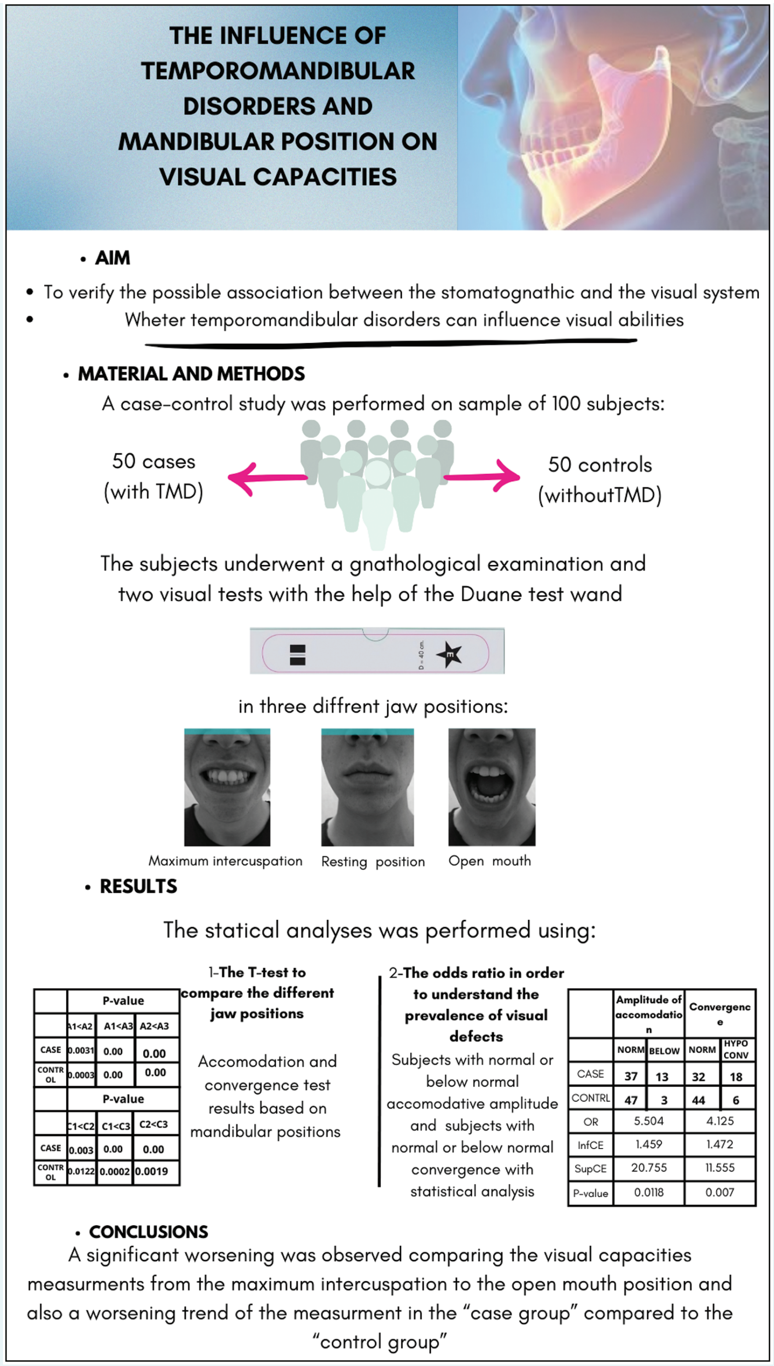

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Introduction

The stomatognathic system is a complex of structures, and the movement of this complex is provided by the TMJ and the masticatory musculature. The TMJ is a bilateral synovial articulation formed by the mandibular and temporal bones, which are connected by an articular disc. The articular capsule and ligaments are parts of the TMJ. In addition, the masticatory musculature includes four pairs of muscles: lateral pterygoid muscle, medial pterygoid muscle, masseter muscle, and temporal muscle.[1]

The organ of vision is responsible for the perception of light and is formed by the eyes and the visual system where the visual system includes the cornea and lens, and the neural system includes the retina and visual cortex. The muscular system of the eye is composed by the extraocular muscles and the intraocular muscles. The extraocular muscles include seven: six of which control the eye movement and there are four recti muscles and the superior and inferior oblique muscles, and the other muscle (levator palpebrae superioris) that controls the eyelid movement. The intraocular muscles include the ciliary muscle, the sphincter pupillae, and the dilatator pupillae; these muscles control accommodation.[2]

The stomatognathic system and the visual apparatus appear to be closely linked through neurological pathways. The first experiment conducted to verify the relationship between masticatory and visual function, developed between 1973 and 1976 by Meyer and Baron,[3] describes the existence of afferents which, from periodontal receptors, go toward the sensory and midbrain nuclei of the trigeminal nerve and, from the latter, through the medial longitudinal fasciculus, reach the motor nuclei of the oculomotor, trochlear, abducens, and accessory nerves (the third, fourth, sixth, and eleventh cranial nerve, respectively). The trigeminal nerve is the fifth cranial nerve; it is divided into three main branches (the ophthalmic, maxillary, and mandibular nerves) that provide sensory and motor innervation to the head and neck region. These branches join at the trigeminal ganglia, which is located in the Meckel's cave of the middle cranial fossa.

Two pathways start from the trigeminal midbrain nucleus: an ascending pathway sends proprioceptive information to the oculomotor and trochlear nuclei and a descending pathway, which sends the same information to the motor nuclei of the abducens and accessory nerves. It appears that[4] the nucleus sends fibers both to mechanoreceptors for regulation of bite force and to oculomotor nerves for ocular muscle spindles; moreover, the dissection of the ophthalmic branch of the trigeminal nerve is followed by a degeneration of the neuromuscular spindles of the extrinsic muscles of the eye.[5]

Other experiments[6-8] conducted from 1955 to 2000 were performed using the HRP which, by staining the axons, identifies the neuronal pathway from the site where it is injected: numerous studies confirmed the presence of HRP at the level of Gasser's trigeminal ganglion after the injection of the same at the level of the extrinsic ocular muscles. When the marker was injected into the masticatory and extraocular muscles, marked cells were found in both cases in the ipsilateral part of the trigeminal midbrain nucleus, confirming the existence of a trigeminal-mediated proprioceptive afferent of the extrinsic ocular muscles. All these studies demonstrate that the proprioception of extraocular muscles, periodontal receptors, dental pulp, masticatory muscles, and TMJ receptors find anatomical contiguity in the mesencephalic nucleus of the trigeminal nerve.

Furthermore, it appears to be a connection between the trigeminal midbrain nucleus and the superior colliculi, which have a sensorimotor integration function due to their anatomical connections with multiple sensory and motor systems (especially the visual pathway), suggesting that intraoral somesthetic sensations also play an important role in the afferents additionally to tactile, visual, and auditory sensations.[9-11] Therefore, the nervous and biochemical connections between the organ of vision and the stomatognathic system seem undeniable.[12,13]

The correlation between TMD and visual defects is not established, and actually, there is not a lot of recent studies on the topic, so further research on this link will be necessary. Among these researches, some studies showed a correlation between visual defects (like myopia and astigmatism) and malocclusions (in particular class II and crossbite).

Some authors have observed alterations in visual capacities (reduction of ocular convergence) in subjects with TMD. Sharifi Milani *et al.*[14] demonstrate that the application of an occlusal repositioning appliance and the alteration of the dental occlusion causes an alteration on visual capacities, that is, reduced when the appliance is removed.

Monaco *et al.*[13] find a worse convergence in subjects with TMD; Cuccia and Caradonna[15] demonstrate alteration in the binocular function in patients with dislocation of the temporomandibular disc, and Vompi *et al.*[16] evidence of the dysfunction in the extrinsic muscles of the eye in patients with scheletric orthognathic dysfunction.

Recent studies[13,14,17] analyze central sensitization and bioelectric activity of masticatory muscle in subjects with myopia and find higher scores on the central sensitization inventory in subjects with axial myopia compared to subjects without refractive error.

Based on these neuroanatomical and clinical observations, we support the existence of a possible relationship between the two systems, and in particular with this study, we want to assess whether jaw positions can modify visual capacities (ocular convergence and accommodation)[18] and consequently, if TMD can influence visual abilities.

Materials and Methods

A case-control study was conducted at the Operative Unit of Odontostomatology of ASST Santi Paolo e Carlo, University of Milan, for a one-year duration from September 2020 to September 2021.

The study examines 100 subjects ages between 16 and 55 [Table 1]. Fifty individuals represented the "case group" (nine men and 41 women) and were patients of the gnathology department suffering from TMD. The remaining half of the subjects represented the "control group" (20 men and 30 women) and were patients from other departments of the odontostomatology unit who were healthy from a gnathological point of view.

The main eligibility criterion was biological age: all subjects over 55 years old were excluded from the research given the possibility of a physiological decline in visual capacity; patients from the "case group" were paired with patients from the "control group" in a way to prevent substantial age gaps between the two subjects, five years of age difference at most.

The partition criterion for the two groups consisted of as follows:

- The presence of one of the following TMD: arthrosis, muscle contracture, reducible dislocation, and non-reducible dislocation for subjects of the "case group."
- The absence of joint pain and noise from the TMJ for subjects of the "control group."

Exclusion criteria for both groups were as follows: patients with removable total dentures, partial dentures, and/or dental implants; patients with a history of tumors in the head and neck region; patients with mandibular fractures and recent dental surgery, infections, chronic systemic inflammatory, or degenerative neurological disorders.

The two groups were subjected to gnathological examination that aimed to exclude pain, noise, or limitation of present or past movement of the temporomandibular system for the "control group." For the "case group," both muscular and articular components were analyzed, to diagnose symptomatic patients, TMJ, and muscular pathologies, and where necessary, the following imaging techniques were used: orthopantomography, TMJ stratigraphy, and nuclear MRI of the TMJ, to help associate a certain subject with the corresponding TMD subclass.

Then, the subjects underwent two orthoptic assessments, the "convergence test," and the "accommodation test" that were carried out allowing subjects with refractive defects (myopia, hypermetropia, presbyopia, and astigmatism) to wear glasses or contact lenses so that all subjects could be considered as emmetropic. Orthoptists use this kind of test in the screening evaluation of the general population to understand if a visual problem is present. We decided to use this test because it is easy to perform and reproducible.

Both tests were performed in three different jaw positions: maximum intercuspation (A1-C1), resting position (A2-C2), and open mouth (A3-C3), aiming to understand whether the different positions of the stomatognathic apparatus could have any influence on visual ability in terms of improvement or deterioration [Figure 1].

Convergence test

The convergence test expresses the possible presence of neuromuscular disorganization in the expression of extraocular muscle tone. The examination is carried out using a fixation target, that is, an object that must

Table 1: Characteristics of case and control group

Case group health status		Arthrosis		Muscular disorders		Disc displacement with reduction		Disc displacement without reduction	
Parameters		Freq	*P* value	Freq	*P* value	Freq	*P* value	Freq	*P* value
Sex	F	11 (22%)	0.775	12 (24%)	0.132	8 (16%)	0.854	10 (20%)	0.098
	M	2 (4%)		5 (10%)		2 (4%)		0 (0%)	
Age		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
		36.85	15.08	33.94	11.99	24.45	11.56	21.9	9.96

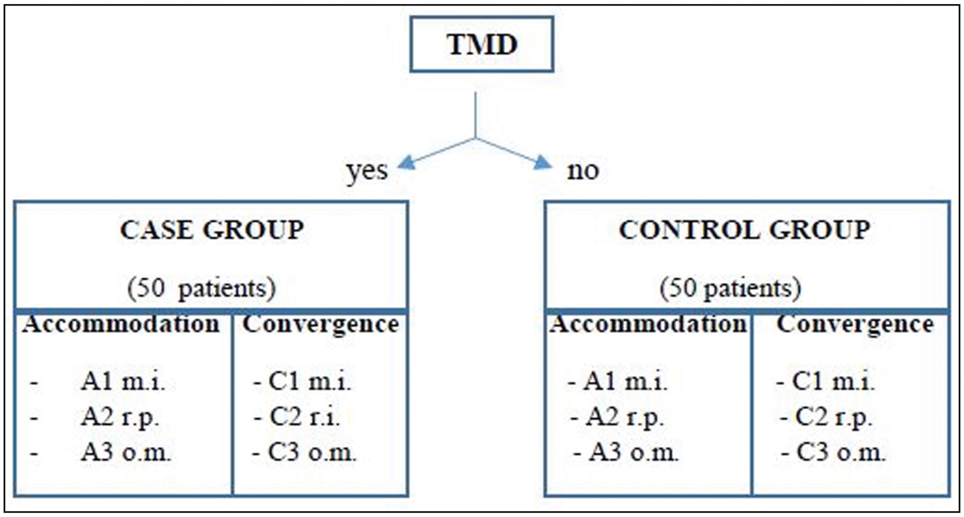

Figure 1: Jaw positions for accommodation and convergence testsm.i.: max intercuspidation, r.p.: rest position, o.m.: open mouth

be continuously observed by the test subject (stick of Duane's test). The subject focuses on the star with the central E, positioned at the midline level of the face, and in the middle of the line where the eyeballs join at about 40 cm from the root of the nose.

Then, the fixation aim is brought toward the tip of the nose, observing the reaction of the eyes when they converge, that is, when the eyeballs rotate medially toward the nose. With the aid of a ruler, the distance at which one eye deviates laterally is then measured since it can no longer maintain binocular vision and consequent convergence. The point where the eye deviates is called the "breakpoint." It is the nearest point of convergence. We applied the range of normality described in Cooper and Jamal's Major Review,[19] which classifies as hypo-convergent all subjects that present a "breakpoint" greater than 7.5 cm.

Accommodation test

The accommodation represents the ability to focus on objects at different distances, thanks to the change in curvature of the crystalline lens. For the accommodation test, the fixation target is represented by the thin vertical line placed in the middle of the two black rectangles, in the opposite pole of the "stick" of Duane. The tested subject focuses on the line at the same distance of the previous test; the stick, then, is brought closer to the tip of the nose, and the subject is asked to report the first signs of "blurring" of the central vertical line or its disappearance.

Using a ruler, a measurement of the distance at which the "blurring" occurs is taken, which corresponds to the NPA, that is, the point closest to the eye that can be seen clearly with accommodation at its maximum.

By using the Donders formula, we can transform the measurement of the NPA in the AA, i.e., the variation of accommodative power that the crystalline lens is capable of performing, as follows: AA = (NPA) − (FPA); in this formula, FPA is the farthest point of accommodation, that is, the farthest point at which an object can be seen clearly. The NPA corresponds to the value of the AA, if the FPA is set at infinity, and this is possible because we considered all subject's emmetropes. The results obtained in centimeters were then transformed into diopters by calculating the inverse of the distance calculated in meters; this allowed the comparison between the AA found in our subjects and the normal AA found in healthy subjects calculated using AA the Hofstetter formula in which the AA is derived empirically based on the age variable only (AA = 15−0.25 × age). This formula calculates the value of AA that a certain individual should have at a specific time; if the AA measured resulted lower than the average AA; the subject was to be categorized as "pathological" for the accommodative variable.

To differentiate blurring from the double vision of the fixation target, the accommodation test was carried out in monocular vision (with only one eye), while the convergence test was performed in binocular vision (a necessary condition).

Statistical analysis

The statistical analyses were performed using the software SPSS program 24.0 for Windows (SPSS Inc., Chicago, IL, USA). To verify the first objective, the mean of the measured data was calculated, and the *t*-test was performed to demonstrate a discrepancy between the statistically determined means. Each hypothesis was considered statistically significant when P value < 0.05. Likewise, to evaluate whether TMDs represented a worsening factor for the accommodative amplitude and oculomotor function, the statistical significance was determined by calculating the odds ratio (OR), inf CE, sup CE, and P value. Since the indices, inf CE and sup CE indicate the range of values within which the OR fluctuates: when inf CE > 1 and P value < 0.05, statistical significance was confirmed.

Results

This study included 100 patients, 50 of which suffered from TMD (case group) and 50 who were gnathologically healthy (control group). Subjects over 55 years old were excluded from the research, and only the four categories of TMD previously mentioned were considered to assign patients to the case group. In the data collection of visual tests, no outliers were found.

The average age of the case group was 36.85, with a standard deviation of 15.08. The control group included 30 women and 20 men. The average age of the sample was 32.46, with a standard deviation of 11.73 [Table 1].

Relationship between jaw position and visual abilities

The comparison between the average measurements collected from the tests performed by the "case" and "control" groups. [Table 2] shows as follows:

- The maximum and minimum values in the accommodation test correspond, respectively, to positions A3 in the "case group" (15.01 cm) and A1 in the "control group" (9.89 cm). Likewise, C3 in the "case group" (8.82 cm) and C1 in the "control group" (5.25 cm).
- A general trend of worsening of the measurements from the maximum intercuspation to the open mouth state, passing through an intermediate value in the resting position.
- The worst results found in the measurements of the "cases" compared to the "controls": the average measurements of the "control group" are always smaller than the corresponding mandibular positions in the "case group." The lowest difference between the averages corresponds to the discrepancy expressed in centimeters between posture 2 and posture 1, while the highest result always occurs between posture 3 and posture 1, showing that the test value determined with the mouth open is very different in all cases compared to the other situations [Table 3].

The values analyzed represent only a weighted average, so hypothetically some isolated extreme measurements could distort the results obtained. For that purpose, an investigation was performed with the aim to find how often a specific mandibular position turned out to have the worst score of the three total positions:

- For the accommodation test, in 82 out of 100 measurements, the open mouth position turned out to be the worst result out of the three mandibular positions; this was followed by an equal value for all three postures (11%), resting position (6%) and maximum intercuspation (1%) [Table 4].
- For the convergence test, C3 was found to be the worst occlusal variable 66 times out of 100; an equal value in the three mandibular positions was found in 27% of the measurements; the C2 resting position emerged in four positions out of the total as the worst; finally, the maximum intercuspation was found to be the least frequent (3%) [Table 4].

The statistical analysis, performed with a student t-test, shows a statistically significant discrepancy between the result averages. In all cases, the P value index was <0.05.

TMD and visual capacity

All the subjects have been listed in Table 5, divided into "case" and "control," with normal or below-average ("pathological") accommodation and convergence. Below-average accommodative capacity values were found in a ratio of 13 to 3 in cases and controls, respectively.

As far as the convergence test is concerned, the results obtained [Table 5] show three times as many subjects with hypo-convergence in the "case group" compared to the "control group" (ratio of 18 to 6).

Table 2: Averages of measurements in cases and controls in the different mandibular postures

	A1	A2	A3	C1	C2	C3
Case	13.01 cm	13.5 cm	15.01 cm	6.93 cm	7.48 cm	8.82 cm
Control	9.89 cm	10.46 cm	11.43 cm	5.25 cm	5.46 cm	5.98 cm

Table 3: Difference expressed in centimeters between average in one position and average in another position and statistical analysis

	A2-A1			A3-A1			A3-A2		
	Mean	S.D.	*P* value	Mean	S.D.	*P* value	Mean	S.D.	*P* value
Case	0.49 cm	1.21 cm	0.006	2 cm	2.15 cm	0.0001	1.51 cm	1.80 cm	0.0001
Control	0.57 cm	1.088 cm	0.001	1.54 cm	1.82 cm	0.0001	0.97 cm	1.11 cm	0.0001
Case vs. Control	0.08 cm	0.23 cm	0.729	0.46 cm	0.4 cm	0.252	0.54 cm	0.3 cm	0.074
	C2-C1			C3-C1			C3-C2		
	Mean	S.D.	*P* value	Mean	S.D.	*P* value	Mean	S.D.	*P* value
Case	0.55 cm	1.356 cm	0.006	1.89 cm	2.05 cm	0.0001	1.34 cm	1.70 cm	0.0001
Control	0.21 cm	0.64 cm	0.024	0.73 cm	1.34 cm	0.0001	0.52 cm	1.21 cm	0.004
Case vs. Control	0.34 cm	0.21 cm	0.112	1.16 cm	0.347 cm	0.001	0.82 cm	0.295 cm	0.007

Table 4: Worst accommodation and convergence test results based on mandibular position

	A1	A2	A3	Equal	*P* value		
					A1 < A2	A1 < A3	A2 < A3
Case	1 (2%)	5 (10%)	41 (82%)	3 (6%)	0.0031	0.00	0.00
Control	0 (0%)	1 (2%)	41 (82%)	8 (16%)	0.0003	0.00	0.00
	C1	C2	C3	EQUAL	*P* value		
					C1 < C2	C1 < C3	C2 < C3
Case	2 (4%)	1 (2%)	36 (72%)	11 (22%)	0.003	0.00	0.00
Control	1 (2%)	3 (6%)	30 (60%)	16 (32%)	0.0122	0.0002	0.0019

Table 5: Percentage of subjects with normal or below-normal accommodative amplitude (AA) and percentage of subjects with normal or below-normal convergence (C) with statistical analysis

	Amplitude of accommodation		Convergence	
	Normal	Below-average	Normal	Hypo-convergence
Case	37 (74%)	13 (26%)	32 (64%)	18 (36%)
Control	47 (94%)	3 (6%)	44 (88%)	6 (12%)
Odds ratio (OR)	5.5045		4.125	
Inf CE	1.4598		1.4725	
Sup CE	20.7557		11.5552	
P value	0.0118		0.007	

Discussion

Our research shows the influence of the jaw position on the visual system. For the accommodation, a higher value indicates a lower accommodative capacity; while a higher convergence value indicates a lower neuromuscular capacity. The results show that maximum occlusal contact can lead to improvements in both accommodation and convergence. Conversely, an increasing distance between the dental arches generates progressively worse results.

These data lead to the hypothesis that oro-facial afferents may involve physiological synaptic interconnections with the visual neural apparatus and therefore can produce improving or worsening effects in the functioning of both intrinsic (accommodation) and extrinsic (convergence) ocular muscles.[20,21] Clinically, these concepts are important because it is possible to hypothesize that some individuals have better visual capacities when the teeth are in contact. Furthermore, jaw posture disorders can lead to a TMD.[22]

For this reason, in the second part of our study, we investigated the correlation between TMD and visual function. The results show a worsening tendency in the values of the "case" group when compared to those of the "control" group. It appears that TMD could be a risk factor for the development of visual problems. The results concerning the connection between TMD and oculomotor function confirm what has been reported in the international literature:[23-25] Nociceptive stimuli due to inflammation of the temporomandibular compartment could trigger nervous system dysfunctions influencing the extrinsic ocular musculature.

These two concepts (jaw position related to visual capacities and higher prevalence of vision defects in patients with TMD) are related to each other. We can hypothesize, for example, that an individual who repeatedly tends to close his teeth to have better visual capacities, over time, could develop a TMD precisely due to this posture defect, which involves an incorrect rest position of the jaws.[26] In particular, our research is useful for clinicians treating patients with TMD who might contact their teeth to have better vision.

On a final note, we hope and aim to understand whether treating TMDs improves visual functions over time by including more accurate orthoptic tests, high levels of incisiveness (randomized clinical trials), and a larger number of subjects. Longitudinal studies can be made to assess whether treating TMDs improves visual functions such as ocular accommodation and convergence over time.

On that perspective, it could be interesting to investigate the effectiveness of occlusal therapy in managing both TMD symptoms and visual impairments. Multicenter clinical trials could explore the neurophysiological pathways linking the stomatognathic and visual systems, using neuroimaging techniques to observe brain activity changes in patients with TMD during jaw movements and consider new diagnostic tools that simultaneously measure jaw function and visual performance to provide a more integrated approach to diagnosing and treating TMD.

Conclusions

Our results show a statistically and clinically correlation between some orthoptic and gnathological variables: we obtained better values in visual accommodation and oculomotor function at maximum intercuspation. From a clinical point of view, these results may suggest that the presence of occlusal contacts could influence positively some visual abilities.

Secondly, it appears that TMDs are a risk factor for the development of visual disturbances because subjects with temporomandibular problems perform the visual test worse than healthy subjects. It is recommendable to treat TMDs to prevent the development of vision defects.

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Conflicts of interest

There are no conflicts of interest.

Authors contributions

AM and AS have contributed to the analysis and interpretation of the statistical data and the conception of the manuscript; DB, CP, RM, and AR have given substantial contributions to the acquisition of the data. All authors have contributed to the drafting of the manuscript, and they have read and approved the final version of the manuscript.

Ethical policy and institutional review board statement

The study was carried out following the Helsinki Declaration on Human Clinical Research. The authors confirm that the Ethics Committee of institute is aware of the work carried out. Nevertheless, written approval from the Committee was not considered necessary and therefore not requested given the fact that the procedures applied in this case study were observational only and did not include treatment of the patient. All participant patients of the research have provided a written consent and a signed disclaimer to use and publish data from their medical records.

Patient declaration of consent

Not applicable.

Data availability statement

Not applicable.

List of Abbreviations

A1	Accommodation in maximum intercuspation
A2	Accommodation in resting position
A3	Accommodation in open mouth position
AA	Amplitude of accommodation
C1	Convergence in maximum intercuspation
C2	Convergence in resting position
C3	Convergence in open mouth position
FPA	Far point of accommodation
HRP	Enzyme Horseradish Peroxidase
M.I.	max intercuspidation
MRI	Nuclear magnetic resonance imaging
NPA	Nearest point of accommodation
NPC	Near point of convergence
O.M.	open mouth
OPT	Orthopantomography
R.P	rest position
TMD	Temporomandibular disorders
TMJ	Temporomandibular Joint

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